ND HAMMEL

find values of $R_{\rm E}$ given in Table I act the second order terms in the calsure.

ons concerning the flow of heat have heat by the ordinary diffusive mechaoy the counterflow mechanism. That iering the results of Zinovieva (10) ient; when these are applied to the nount of heat carried by the normal ders of magnitude smaller than that en at the largest ΔT 's.

is that the kinetic energy associated at flow by internal convection. The end of the slit will be conveyed as nal fluid convection. The total heat

$$\mathbf{\bar{v}}_{a} + \frac{1}{2}\rho_{s}v_{s}^{2}\mathbf{\bar{v}}_{s} . \tag{37}$$

a and defining $\mathbf{q}_i(z)$ as the heat eurint z in the slit, i.e., $\mathbf{q}_i(z) = \rho s T \mathbf{v}_n$,

$$\frac{-\rho_s^2}{\rho_s T} \left(\frac{\tilde{\mathbf{q}}_i(z)}{\rho_s T} \right)^2 \right]. \tag{38}$$

Il for temperatures above 1.1°K and eriments under discussion, except in 2°K the maximum value of this term here $\rho_s = \rho_n$ it is of course zero; and is kinetic energy terms cannot appreits.

section is the influence upon the heat s through shear. According to the two a truly classical fluid with a classical ume per second by shear may be exaction Φ in the form used by London

$$\left(\frac{1}{2}\right)^{2} + \eta' (\nabla \cdot \mathbf{v}_{n})^{2}.$$
 (39)

ons made previously, the dominant (39) becomes upon averaging across the slit:

$$\Phi = \frac{12\eta_n \bar{\mathbf{v}}_n^2}{d^2} = \frac{\bar{\mathbf{q}}_n^2}{T \,\lambda d^2} \,. \tag{40}$$

The total amount of heat generated in the slit per second through the action of viscous forces may be found by integrating this expression over the volume of the slit:

FLOW OF LIQUID HE II

$$\dot{Q}_{\Phi} = -\int \Phi \, dV = -\int_{0}^{d} \int_{0}^{w} \int_{0}^{L} \frac{\bar{q}^{2}}{T\Lambda d^{2}} \, dx \, dy \, dz = \frac{w}{d} \int_{T_{0}}^{T} \frac{\bar{q}^{2}}{T\Lambda} \, \frac{dz}{dT} \, dT$$

$$= -w d\bar{q} \int_{T_{0}}^{T_{1}} \frac{dT}{T(1+\alpha d^{2}\bar{q}^{2})}$$
(41)

Using (25) and assuming in the first approximation that the heat generated does not appreciably perturb the temperature gradient in the slit.

In the lower temperature range we may neglect $\alpha d^2 \bar{\mathbf{q}}^2$ compared with unity and Eq. (41) becomes

$$\dot{\mathbf{Q}}_{\Phi} = -w \, d\bar{\mathbf{q}} \ln T_1 / T_0 \,. \tag{41a}$$

Clearly this term is comparable in magnitude with the total heat $\dot{\mathbf{Q}} = w \, d\bar{\mathbf{q}}$ and it would at first sight appear that dissipative processes might appreciably affect the over-all heat transport for a given temperature difference. We shall now show that this is not the case, and that in fact the Rayleigh term is responsible for normal fluid generation resulting in the increase in the normal fluid flux between the hot and the cold ends of the slit.

The average normal fluid flux entering the slit at the hot end of the slit is $\overline{\mathbf{N}}_1 = (\rho_n \overline{\mathbf{v}}_n)_1 \operatorname{gm/cm}^2$ -sec and that leaving the cold end is $\overline{\mathbf{N}}_0 = (\rho_n \overline{\mathbf{v}}_n)_0 \operatorname{gm/cm}^2$ -sec. The change in flux is then $\overline{\Delta \mathbf{N}} = (\rho_n \overline{\mathbf{v}}_n)_1 - (\rho_n \overline{\mathbf{v}}_n)_0 \operatorname{gm/cm}^2$ -sec and we assert that this difference arises from the generation of normal fluid within the slit by viscous forces. The effect of normal fluid generation in the slit may be included in the equation of continuity in the manner suggested by Zilsel (30):

$$\frac{\partial \rho_{n}}{\partial t} + \nabla \cdot \rho_{n} \mathbf{v}_{n} = \Gamma$$
(42)

where $\Gamma(\text{gm/cm}^3\text{-sec})$ represents the generation term for normal fluid (there is of course an equal sink term for superfluid). In steady state flow the time derivative vanishes, and the total change in normal fluid flux may be found by integrating (42) throughout the slit volume. The heat required to generate Γ is $\Gamma s_{\lambda} T$ (the lambda point entropy s_{λ} enters because Γ refers to generation of hormal fluid alone rather than fluid of density ρ_n , and the approximation $\rho_n/\rho = s/s_{\lambda}$, valid in the temperature range of interest, is used). Neglecting for the moment dissipation arising in the Gorter-Mellink term we identify this heat